

# NEXT GENERATION P-BAND PLANETARY SYNTHETIC APERTURE RADAR

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## ABSTRACT

The Space Exploration Synthetic Aperture Radar (SEsar) is an advanced P-band beamforming radar instrument concept to enable a new class of observations suitable to meet Decadal Survey science goals for planetary exploration. The radar operates at full polarimetry and fine (meter scale) resolution, and achieves beam agility through programmable waveform generation and digital beamforming. The radar architecture employs a novel low power, lightweight design approach to meet stringent planetary instrument requirements. This instrument concept has the potential to provide unprecedented surface and near-subsurface measurements applicable to multiple Decadal Survey Science Goals.

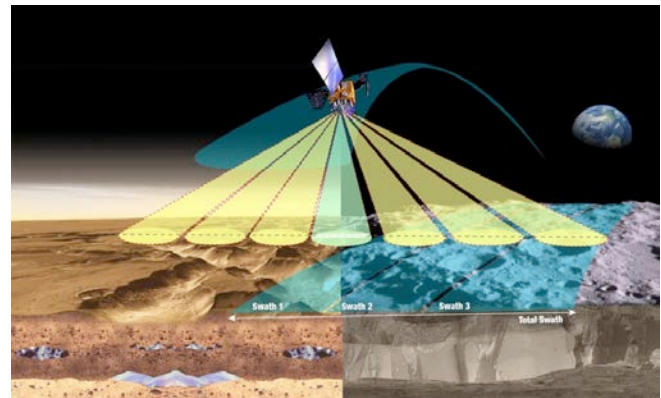
**Index Terms**— SAR, digital beamforming, planetary, exploration, radar.

## 1. INTRODUCTION

The Space Exploration Synthetic Aperture Radar (SEsar) is a “next generation” P-band (70 cm wavelength) radar instrument with capabilities beyond current planetary instruments and ideally suited to meet a number of Decadal Survey Science Goals [1]. The instrument’s operation, characterized by full polarimetry, high resolution (< 6 m), and programmable beams, have the potential to provide unprecedented planetary surface and near-subsurface measurements. The instrument design is based on a modular, low power, lightweight architecture that allows the customization of the instrument configuration for specific planetary body, such as Mars or the Moon. Advanced features, such as multiple RF channels, programmable waveform generation, and digital beamforming provides SEsar with enhanced capabilities to help answer key questions in planetary science.

Multiple decadal survey science goals [1] require fine resolution views of subsurface stratigraphy, and the ability to expose bedrock and search for buried features that hold clues about the geologic history. For example, locating habitable regions, finding water, and determining the hydrology and cryosphere evolution is a primary goal of the Mars exploration. SEsar’s long wavelength signals would penetrate through meters of material, image buried surfaces

[2] at fine spatial resolution and full polarimetry, and provide information to identify signatures of buried ice and water [3].



**Figure 1** SEsar is a P-band (70 cm wavelength) digital beamforming radar system that is modular and can be used for imaging polarimetry of Earth and rocky planets and moons, as well as asteroids and comets.

On the Moon, SEsar would be able to image through meters of surface-covered regolith and provide information to characterize the near-surface stratigraphy and geology, crucial in the understanding of lunar processes and in the identification of landing sites for future lunar missions. SEsar’s fine resolution mapping and polarimetry would also provide details about the volcanic processes that built the lunar mare and to locate and track lava tubes [4], important for both science and future exploration purposes.

## 2. INSTRUMENT ARCHITECTURE

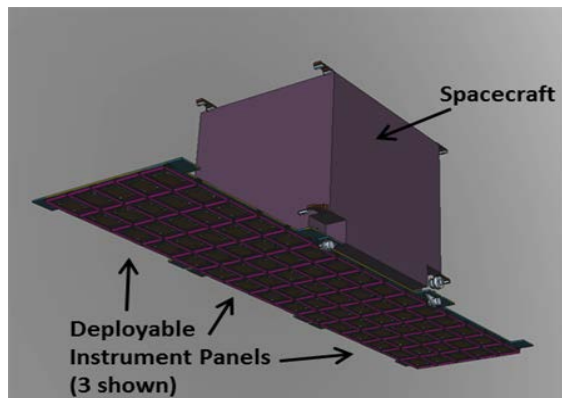
SEsar employs a multiple-input multiple-output (MIMO) and modular approach that distributes the radar systems into instrument panels composed of “smart” active subarrays, as illustrated in Fig 2. The radar architecture is fully programmable and capable of multi-mode radar operation including polarimetric SAR imaging, nadir SAR altimetry, and scatterometry. Some of its advanced programmable features include single, dual, or full polarimetry; multi-look angle data collection; simultaneous left and right of the track imaging; selectable resolution and swath width; digital beam steering (no moving parts); and beam pattern control; among

others. This radar design is based off the successful the P-band EcoSAR and the L-band DBSAR airborne radars that were developed at the NASA Goddard Space Flight Center [5], [6]. Table 1 lists some of SESAR's main characteristics.

Under the technology-development program awarded by NASA's Planetary Instrument Concepts for the Advancement of Solar System Observations program (PICASSO), the SESAR team is developing innovative techniques to reduce the mass and power consumption of the radar.

SESAR will use a distributed digital electronics architecture that implements advanced waveform modulation techniques to provide the full beam steering agility while significantly reducing the system power consumption. This approach reduces the number of digital-to-analogue converters (DACs) and analogue-to-digital converters (ADCs) and enables centralized waveform generation and data acquisition with reduced power and mass. SESAR's antenna will be based on a proven design developed for EcoSAR [7]. The SESAR team will use innovative techniques to reduce the weight of the antenna.

Using these innovations, SESAR will be able to synthesize multiple antenna beams, simultaneously or interleaved, permitting the implementation of non-conventional imaging that can overcome fundamental limitations of conventional radar systems [8],[9],[10]. Some of its benefits include an increase in the measurement swath without reducing the received antenna gain, and the suppression of ambiguities or localized interference in the receiver signal by appropriate null-steering of the antenna pattern. The antenna gain, beam pointing angle, and sidelobe structure can be programmed in real-time for specific tasks. Furthermore, multiple beams can be synthesized on both sides of the flight-track, as well as nadir, using a single nadir-looking antenna, thus increasing the coverage area.



**Figure 2 SESAR employs a modular approach that permits customizing the architectures for a given planetary mission. SESAR's distributed architecture enables advanced operational**

**Table 1 SESAR's main characteristics**

<b>Frequency</b>	435 MHz (P-band)
<b>Wavelength</b>	0.69 m
<b>Max Bandwidth</b>	100 MHz
<b>Pulse Width</b>	40 $\mu$ s
<b>Polarization</b>	HH, VV, VH, HV
<b>Noise Equivalent <math>\sigma_0</math></b>	-29 dB
<b>Slant Range Resolution</b>	1.5 m
<b>Max. Transmit Power</b>	300 W
<b>Beam Steering Range</b>	$\pm$ 45 degrees
<b>Antenna Size</b>	3.5 m x 7.9 m

### 3. CONCLUSION

The SESAR instrument approach would be a first in planetary exploration. SESAR's agile radar operation, modularity, and multimode operation, while using technology that can be optimized to produce the best possible data set for the individual science goals, will help pave the way for the next generation planetary radar systems. SESAR's innovative approach to lower mass and power consumption will make these future missions feasible.

### 4. REFERENCES

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